REMARKS

Prior to this Reply, Claims 1-19 and 21-42 were pending. Through this Reply, Claims 1, 5-16, 18, 19, 21, 25-33, 41 and 42 have been amended; Claims 2-4, 17, 22-24 and 34-40 have been cancelled without prejudice to, or disclaimer of, the subject matter contained therein; and, Claims 43-85 have been added. Accordingly, Claims 1, 5-16, 18, 19, 21, 25-33 and 41-85 are now at issue in the present case.

I. Claims Rejections

The Examiner rejected Claim 38 under 35 U.S.C. 102(e) as being anticipated by U.S. Patent No. 6,288,856 to Ottesen et al. (hereinafter "Ottesen").

The Examiner also rejected Claims 1, 2, 5, 7, 16-19, 21, 22, 26 and 37 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen in view of U.S. Patent No. 4,929,894 to Monett (hereinafter "Monett").

The Examiner also rejected Claim 39 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen in view of U.S. Patent No. 6,100,683 to Lim (hereinafter "Lim").

The Examiner also rejected Claims 3, 4, 23, 24 and 25 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen and Monett in view of Lim.

The Examiner also rejected Claims 6, 8, 25 and 32 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen and Monett in view of U.S. Patent No. 6,252,731 to Sloan (hereinafter "Sloan").

The Examiner also rejected Claims 9 and 27 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen and Monett in view of U.S. Patent No. 6,513,141 to Livingston (hereinafter "Livingston").

The Examiner also rejected Claims 10, 12, 28 and 30 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen, Monett and Livingston in view of Sloan.

The Examiner also rejected Claims 13, 14, 31, 33, 34 and 36 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen and Monett in view of U.S. Patent No. 5,793,548 to Zook (hereinafter "Zook").

The Examiner also rejected Claim 15 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen, Monett and Zook in view of U.S. Patent No. 6,381,203 to Muramatsu (hereinafter "Muramatsu").

The Examiner also rejected Claim 39 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen in view of U.S. Patent No. 6,208,476 to Park (hereinafter "Park").

The Examiner also rejected Claim 40 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen in view of Zook.

The Examiner also rejected Claim 41 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen in view of Muramatsu.

The Examiner also rejected Claim 42 under 35 U.S.C. § 103(a) as being unpatentable over Ottesen in view of U.S. Patent No. 6,411,452 to Cloke (hereinafter "Cloke").

Ottesen discloses a disk drive that estimates head-to-disk clearance (fly height) to identify poorly performing heads. The disk drive exploits the principle that narrower pulses represent smaller head-to-disk clearance and wider pulses represent larger head-to-disk clearance. The disk drive calculates the differentiated edge slope, the area portion, or the width of several isolated pulses to determine the pulse shapes, and then averages these calculations to reduce variations due to disk coersivity and air turbulence. Furthermore, the isolated pulses are substantially free of intersymbol interference and filter dynamics to avoid shape alterations.

Monett discloses a disk drive that simultaneously performs missing pulse and additional pulse tests on a disk to increase quality control throughput. An input waveform is delayed by one period, and a difference between the input waveform and the delayed version is compared with a missing pulse threshold and an additional pulse threshold.

Claims 1 and 21 have been amended to further clarify the claimed invention.

Claim 1 recites "deriving a value from m of the n samples, wherein the m samples are significant samples that each have an amplitude greater than 50% of an amplitude of an isolated pulse in the read signal and greater than an amplitude of the other samples of the n samples; comparing the derived value to a threshold value; and reporting a flaw in the track if the comparison is unacceptable." Claim 21 recites similar limitations, and the remaining rejected claims that are pending depend from Claims 1 or 21.

Ottesen fails to teach or suggest detecting a flaw in a disk, and Monett fails to teach or sampling a read signal.

Ottesen in view of Monett might suggest a disk drive that estimates head-to-disk clearance to identify poorly performing heads (in Ottesen) and simultaneously performing missing pulse and additional pulse tests to rapidly identify flaws in the disk (in Monett). However, the proposed combination fails to teach or suggest sampling a read signal to detect flaws in the disk, much less using the significant samples set forth in Claim 1.

The Examiner <u>admits</u> that "Ottesen et al. does not explicitly teach [using the isolated pulses to detect a flaw in the disk]." However, the Examiner asserts that "It would have been obvious to a person of ordinary skill in the art, at the time the invention was made, to modify Ottesen et al.'s invention with the teaching of Monett in order to detect flaws in the disk by the examination of the track data."

Ottesen is non-analogous to the present invention. Ottesen is directed to estimating head-to-disk clearance to identify poorly performing heads. The present invention, on the other hand, is directed to detecting flaws in a disk using significant samples of a read signal. Ottesen is neither within the field of the invention (detecting flaws in a disk) nor pertinent to the particular problem with which the inventor was concerned (increasing the signal-to-noise ratio in the samples compared to the threshold value to more accurately distinguish between flaws and noise). Therefore, Ottesen is non-analogous to the present invention and cannot be used to sustain an obviousness rejection.

Ottesen fails to teach or suggest "deriving a value from m of the n samples, wherein the m samples are significant samples that each have an amplitude greater than . . . an amplitude of the other samples of the n samples." Instead, Ottesen estimates the head-to-disk clearance using <u>all</u> of the incoming isolated pulses and makes no attempt to select isolated pulses with larger amplitudes than other isolated pulses to calculate the estimate. Furthermore, selecting the isolated pulses with the largest amplitudes is senseless since the isolated pulses have identical amplitudes (see Fig. 5) and are substantially free of intersymbol interference and filter dynamics to avoid shape alterations.

Ottesen fails to teach or suggest using the isolated pulses to detect disk flaws, and Monett fails to cure this deficiency. Ottesen estimates the head-to-disk clearance based on the principle that narrower pulses represent smaller head-to-disk clearance and wider pulses represent larger head-to-disk clearance (see Fig. 6). However, neither Ottesen nor Monett even remotely suggest that the pulse shape is indicative of disk flaws. Thus, the proposed modification in which Ottesen detects disk flaws like head-to-disk clearance is completely unsupported and strikes Applicant as classic hindsight reconstruction using the present invention as a blueprint.

Ottesen teaches away from using the head-to-disk clearance estimate to detect disk flaws:

> Due to minute local coersivity variations in the magnetic surface coating around a track of interest, such as a track containing di-bits having appropriate properties, and small changes in head-to-disk spacing due to air turbulence, there may be some variation in the maximum value of the derivative signal, y[n]. It is therefore desirable to average the maximum values from several isolated di-bits on one or more tracks. (Col. 9, lines 19-26).

As set forth in MPEP § 2141, in order to be analogous art, the reference must either be in the field of the invention or be reasonably pertinent to the particular problem with which the inventor was concerned.

As set forth in MPEP § 2143, in order to establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all of the claim limitations.

As set forth in MPEP § 2143, if the proposed modification would render the prior art unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification.

As set forth in MPEP § 2142, the Examiner bears the initial burden of factually supporting any *prima facie* conclusion of obviousness.

In view of the above, Applicant believes that the Examiner has failed to meet this burden. Ottesen is non-analogous to the present invention, fails to teach or suggest numerous features of the present invention, and teaches away from a proposed modification that has no support in Monett or any other cited reference and is probably inoperative.

Many of the dependent claims are patentable for reasons in addition to those provided above. Applicant does not admit that the Examiner has met the burden of establishing a *prima facie* case of obviousness with respect to the dependent claims. Accordingly, Applicant may address the dependent claims at a later time, if necessary.

II. New Claims

Claims 43-85 have been added. No new matter has been added.

Claims 43-45 depend from Claim 21 and are allowable for at least the same reasons as Claim 21.

Claim 46 is allowable for at least the same reasons as Claim 1. Claims 47-65 depend from Claim 46 and are allowable for at least the same reasons as Claim 46.

Claim 66 is allowable for at least the same reasons as claim 46. Claims 67-75 depend from Claim 66 and are allowable for at least the same reasons as Claim 66.

Claim 76 is allowable for at least the same reasons as Claim 46. Claims 77-85 depend from Claim 76 and are allowable for at least the same reasons as Claim 76.

III. Other Amendments to Claims

The claims have been amended to improve clarity. No new matter has been added.

IV. Amendments to Specification

A substitute specification without claims (and a marked-up version thereof) is provided herein under 37 C.F.R. 1.125 to improve clarity of the specification. No new matter has been added.

Applicants respectfully request that the substitute specification be entered.

V. Amendments to Drawings

Applicants are submitting replacement Figures 1-3, 4B, 4C and 5-7 (on Replacement Sheets 1-5) to improve the quality of the drawings.

Figure 2 has been modified to delete reference numeral 136a.

Figure 3 has been modified at step 300 to change "polarizations" to "data pattern" and at step 304 to change "take n-1" to "read data pattern from disk to obtain n–1" and at step 308 to change "take a" to "read data pattern from disk to obtain" and at step 312 to change "last" to "previous" and to insert "value" after "threshold" and to delete "are" and "the" and at step 316 to change "signal controller" to "report flaw" and to insert a branch from step 316 to step 308.

Figure 4B has been modified so that the magnetic transitions between magnets 404 are aligned with the magnetic transitions between bit cells 400 in Figure 4A.

Figure 4C has been modified so that peaks 412 are aligned with the magnetic transitions between magnets 404 in Figure 4B and the magnetic transitions between bit cells 400 in Figure 4A.

Figure 5 has been modified to change "A to D sample levels (no Noise)" to "Amplitude".

Figure 6 has been replaced by a new Figure 6.

Figure 7 has been modified at shift register 700 to change "n" to "m" and at comparator 708 to insert "value" after "threshold" and at memory 712 to change "valve" to "value".

No new matter has been added. Figures 1-3, 4A, 4B, 4C and 5-7 constitute all of the drawings of the application.

VI. Additional Claim Fees

In determining whether additional claim fees are due, reference is made to the Fee Calculation Table (below).

Fee Calculation Table

	Claims Remaining After Amendment		Highest Number Previously Paid For	Present Extra	Rate	Additional Fee
Total (37 CFR 1.16(c))	70	Minus	42	= 28	x $50 =	$ 1400.00
Independent (37 CFR 1.16(b))	5	Minus	3	= 2	x $200 =	$ 400.00

As set forth in the Fee Calculation Table (above), Applicant previously paid claim fees for forty-two (42) total claims and for three (3) independent claims. Therefore, Applicant hereby authorizes the Commissioner to charge the credit card identified on the enclosed Form PTO-2038 in the amount of $1800.00 for the presentation of twenty-eight (28) total claims over forty-two (42) and two (2) independent claims over three (3). Although Applicant believes that no other fees are due, the Commissioner is hereby authorized to charge Deposit Account No. 50-2198 for any fee deficiencies associated with filing this paper.

VII. Conclusion

It is believed the above comments establish patentability. Applicant does not necessarily accede to the assertions and statements in the Office Action, whether or not expressly addressed.

Applicant believes that the application appears to be in form for allowance. Accordingly, reconsideration and allowance thereof is respectfully requested.

The Examiner is invited to contact the undersigned at the below-listed telephone number regarding any matters relating to the present application.

Respectfully submitted,

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Marked-Up Version of

Substitute Specification Under 37 C.F.R. 1.125

~~METHOD AND APPARATUS FOR~~ FLAW DETECTION IN DISK DRIVE ~~SYNCHRONOUS SAMPLING (PRML) READ CHANNELS~~ USING SIGNIFICANT SAMPLES OF DATA PATTERN STORED ON DISK ~~POST PROCESSED DIGITAL FILTERS~~

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims p~~P~~riority ~~is claimed~~ from U.S. Provisional ~~Patent~~ Application Serial No. 60/203,088, filed May 9, 2000, ~~entitled "ENHANCED FLAW DETECTION IN SYNCHRONOUS SAMPLING (PRML) READ CHANNELS USING POST PROCESSED DIGITAL FILTERING" and further identified as Attorney Docket No. 3123-354 PROV,~~ the disclosure of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to flaw ~~the~~ detection ~~of flaws~~ in storage~~magnetic~~ media, and i ~~using post processed digital filtering. I~~n particular, ~~the present invention relates~~ to flaw~~the~~ detection ~~of flaws~~ in a disk in a disk drive ~~magnetic media~~ using samples generated by reading a data pattern on the disk~~in a synchronous sampling, partial response maximum likelihood (PRML) read channel using post processed digital filtering~~.

BACKGROUND OF THE INVENTION

D~~Computer d~~isk drives store information on magnetic disks. Typically, the information is stored ~~on each disk~~ in concentric tracks on the disk and the tracks~~that~~ are divided into servo sectors that store servo information and data field~~sectors~~ that store user data. A transducer head reads from and writes to ~~Information is written to or read from~~ the~~a~~ disk. The t~~by a t~~ransducer head is ~~,~~mounted on an actuator arm assembly that~~,~~ ~~capable of~~ moves~~ing~~ the transducer head radially over the disk. Accordingly, the ~~movement of the~~ actuator arm assembly allows the transducer head to access different tracks on the disk. The~~A~~ disk is rotated by a spindle motor at ~~a~~high speed, allowing the transducer head to access different data field~~sectors~~ within each track on the disk. ~~The transducer head may include integrated read and write heads.~~

Fig. 1 illustrates a ~~A typical computer~~ disk drive **100** that ~~is illustrated in Fig. 1. The disk drive 100~~ includes a base **104** and a magnetic disk (or disks) **108** (only one of which is shown~~ in Fig. 1~~). The ~~magnetic~~ disks **108** is~~are~~ ~~inter~~connected to the base **104** by a spindle motor (not shown) mounted within or beneath a~~the~~ hub **112** such that the disks **108** ~~can be~~ rotates~~d~~ relative to the base **104**. An actuator arm assembly~~ies~~ **116** is~~(only one of which is shown in Fig. 1) are~~ ~~inter~~connected to the base **104** by a bearing **120** and suspends~~. Actuator arm assemblies 116 each include~~ a transducer head **124** at a first end. The transducer head **124** reads data from and writes data to~~, to address each of the surfaces of~~ the ~~magnetic~~ disks **108**. ~~The transducer heads 124 typically include read and write elements (not shown).~~ A voice coil motor **128** pivots the actuator arm assembly~~ies~~ **116** about the bearing **120** to radially position the transducer heads **124** relative~~with respect~~ to the ~~magnetic~~ disks **108**. By changing the radial position of the transducer heads **124** relative~~with respect~~ to the ~~magnetic~~ disks **108**, the transducer heads

124 ~~can~~ accesses different tracks ~~or cylinders~~ **132** on the ~~magnetic~~ disks **108**. The voice coil motor **128** is operated by a controller **136** that is ~~in turn~~ operatively connected to a host computer (not shown). A channel **140** processes data~~information~~ read from the ~~magnetic~~ disks **108** by the transducer heads **124**.

~~With reference now to~~ **Fig. 2**~~,~~ illustrates the~~a typical arrangement of data tracks~~ ~~**132** on a magnetic~~ disk **108** in more detail~~is illustrated~~. T~~Usually, t~~he ~~data~~ tracks **132** are divided into data fields **204a-204h** and ~~with a~~ servo sectors **208a-208h** ~~between one or more of the data fields **204a-204h**~~. T~~Generally, t~~he data fields **204a-204h** ~~are used for~~ store~~ing~~ user data and ~~, while~~ the servo sectors **208a-208h** ~~are used for~~ store~~ing~~ servo information~~, that is used~~ to provide the transducer head **124** with its radial ~~positioning information. Typically, at least some of the information contained in the servo sectors **208a-208h** is written during the servo track writing process, and the portions of the servo sectors **208a-208h** containing such information generally cannot be written to after the disk drive **100** is assembled. In particular, the servo sectors **208a-208h** provide the transducer heads **124** with information concerning their~~ position over the ~~magnetic~~ disks **108**.

Although the ~~magnetic~~ disk **108** ~~illustrated in **Figs. 1 and 2** is shown as~~ has~~ving~~ a relatively small number of ~~data~~ tracks **132**, data fields **204** and servo sectors **208**, ~~it can be appreciated that~~ a typical ~~computer~~ disk ~~drive **100**~~ contains a very large number of ~~data~~ tracks ~~**132**~~, data fields ~~**204**~~ and servo ~~or hard~~ sectors ~~**208**~~. For example, ~~computer~~ disk~~-drives~~ ~~**100**~~ having over 30,000 tracks per inch and 120 servo sectors per track are presently available.

~~———~~In addition, alternate configurations of the ~~magnetic~~ disks **108** are possible. For example, ~~in a computer disk drive 100 having several magnetic disks 108,~~ onea surface of ~~one of~~ the disks **108** canmay be dedicated to servo information~~,~~ while the other surfaces of the ~~remaining~~ disks **108** (and any remaining disks **108** in the disk drive **100**) can ~~may be used~~ exclusively ~~to~~ store user data.

Data is ~~generally~~ stored on the disk **108** using data ~~patterns of magnetization~~patterns with magnetic transitions between opposite magnetic polarities. For example, the magnetic polarity ~~ization of the disk 108~~ in a first direction ~~may~~ encodes a digital 1, and~~while~~ thea magnetic polarity ~~ization~~ in a second direction ~~may~~ encodes a digital 0. A bit cell is the shortest length of the track **132** to which a particular magnetic polarity is written. -Accordingly, a ~~transition in~~ magneticz~~ation~~ transition from one bit cell to thea next bit cell indicate~~signal~~s a change from one digital character to another. ~~A bit cell is the shortest length of a track 132 to which a particular magnetic polarity is written.~~

The ~~magnetic~~ disk **108** is ~~is generally~~ formed ~~from a film of magnetically hard material deposited on a substrate. For example, the disk 108 may be formed~~ by depositing a magnetic ~~metal~~ film on a rigid substrate. The thickness of the magnetic film must be closely controlled. Where~~, for example,~~ the magnetic film is too thin, the magnetic flux density produced by a magnetic transition ~~in the thinned area~~ will be too weak~~less than the magnetic flux produced by a magnetic transition in an area of the disk having the specified film thickness~~. The disk **108** may also contain other defects, such as scratches or pits, that degrade the magnetic flux density produced by ~~of~~ a magnetic transition. These defects can ~~may also be affected by other defects on the disk 108, such~~

~~as scratches or pitting~~ occur~~ring~~ during the manufacture of the disk **108**~~,~~ or during the assembly of the disk drive **100**.

~~In order to ensure the reliable storage and retrieval of user data from a disk drive 100, manufacturers generally subject a~~ The disk drive **100** is subject to numerous qualification tests to ensure reliable storage and retrieval of user data once ~~before the disk drive 100 is~~ delivered to an end user. Flaw scan is one such qualification test. Flaw scan ~~testing is generally conducted in order to~~ identifies~~y~~ areas of the disk **108** that may not reliably store~~encode~~ user data. Flaw scan writes a data pattern ~~According to conventional methods of detecting flaws, a pattern of magnetic polarizations is written to those areas of the disk 108 to which write operations are allowed (e.g.,~~ to the data field~~sectors~~ **204** (and any other writable areas of the disk **108**) and then reads the data pattern from the data fields **204** (and any other writable areas of the disk **108**) ~~)~~ following assembly of the disk drive **100**. The magnetic polarity~~zation~~ in the data pattern can ~~may be~~ alternate~~d~~ every bit cell to produce ~~in the data sectors (i.e.,~~ a 1T data pattern,~~),~~ or ~~may be alternated after~~ every i^{th} bit cell to produce ~~to produce~~ an iT data pattern~~,~~ where i is an integer~~ number~~. For instance, the magnetic polarity~~zation~~ can ~~may be~~ alternate~~d~~ every two bit cells to produce a 2T data pattern (110011001100 . . .), every three bit cells to produce a 3T data pattern~~. A 3T data pattern is produced if the data is written to the disk in a~~ (111000111000 . . .) and so on~~pattern~~.

The transducer head **124** generates a read signal in response to reading the data pattern from the disk **108**, and the read signal includes pulses caused by the magnetic transitions in the data pattern. The isolated pulse width (PW50) is the distance between the points of intersection between an isolated pulse and a line indicating 50% of the

maximum amplitude of the isolated pulse. Intersymbol interference is the alteration of an isolated pulse due to linear superposition of other pulses in close proximity.

Data patterns ~~In general, the higher the value of i the greater the signal amplitude, because of decreased intersymbol interference. This is true for iTs that result in data patterns having~~ with long periods (iT) that occupy a length of the track **132** that is greater than the PW50 ~~(*i.e.*, the isolated pulse width)~~ of a read signal derived from the disk **108** cause the transducer head **124** to generate a read signal with greater amplitude due to decreased intersymbol interference. Alternatively, data patterns with short periods that occupy a length of the track **132** that is less than the PW50 increase the likelihood of detecting a flaw or the inability of a particular length of the track **132** to produce the prescribed magnetic flux density.

~~The PW50 is the distance between the points of intersection between an isolated pulse and a line indicating an amplitude that is equal to 50% of the maximum amplitude of the isolated pulse. Alternatively, a shorter period increases the likelihood of detecting a flawed area or the inability of a particular length of track **132** to produce a prescribed magnetic flux.~~

~~A conventional method for detecting flaws in a disk **108** is illustrated in **Fig. 3**. According to such a method, after the chosen pattern of magnetic polarizations has been written to the writable areas of the disk **108** by the write element of the transducer head **124** (step **300**), the read element of the transducer head **124** is used to read back the pattern of magnetic polarizations. In general, the channel **140** samples the varying voltage signal produced by the read element of the transducer head **124** from the pattern~~

~~of magnetic polarizations written to the disk **108** as the track **132** passes beneath the transducer head **124**.~~

T~~In a typical disk drive **100**, t~~he channel **140** includes a partial response maximum likelihood (PRML) detector~~,~~ (not shown) that ~~which allows the~~ accurately detects~~ion~~ the ~~of~~ data patterns ~~of magnetic polarizations~~ even when the user data is ~~densely~~ written on the disk **108** at high bit density and the read signal exhibits intersymbol interference. The PRML ~~In a partial response maximum likelihood type~~ detector samples~~,~~ the ~~amplitude of~~ read~~a~~ signal ~~is sampled~~ at regular time intervals and ~~,~~ determines a ~~A~~ code word that symbolizes a set of pulses ~~symbolized by a set of pulses is then determined~~ using a statistical maximum likelihood or Viterbi process. ~~Accordingly, the targeted shape of a pulse is determinative in decoding a stored code word. The advantage of the PRML type detector is that the density of data, known as the user bit density (UBD), may be increased as compared to peak detection methods.~~

~~In general, peak detection methods must detect discrete bits of data. Thus, when pulses are densely packed such that the signal derived from a first bit is distorted, *e.g.*, by intersymbol interference, peak detection methods are incapable of reliably decoding pulses. In contrast, the PRML type detection method allows for the accurate detection of bits even when the pulse that would be generated by a bit in isolation is altered by its proximity to other bits (*i.e.*, is altered by intersymbol interference due to the linear superposition of the pulses).~~ For instance, the PRML detector ~~disk drives may accurately~~ detects a data pattern ~~series of bits~~ when the ~~isolated pulse width (~~PW50~~) of a signal~~ contains 2.5 bits of information. Accordingly, the~~a~~ PRML detector allows user data to be recorded at higher density than a peak detector since the peak detector is incapable of

reliably decoding pulses with intersymbol interference~~allows for information to be recorded at increased user bit densities~~.

T~~Flaw scanning techniques typically take advantage of the characteristics of the channel. For example, ~~he channel **140** often uses a 2T preamble ~~is often used by the channel~~ to synchronize sample times (~~*i.e.*~~ phase) and ~~to~~ determine signal ~~the~~ amplitude ~~of signals in the channel~~ to adjust ~~allow~~ the gain ~~to be properly adjusted~~. When the phase and gain are properly adjusted, a 2T sampled waveform in the channel **140** produces a ~~very~~ distinctive pattern. Furthermore, ~~In a conventional~~ flaw scan often uses ~~ning technique,~~ a ~~the~~ 2T data pattern ~~is often used~~ because of the high magnetic ~~flux~~ transition rates, ~~the relative~~ low intersymbol interference, availability in the channel **140** and ~~the~~ unique sampled pattern it produces in the channel **140**.

Fig. 3 is a flow chart of a conventional flaw scan. The transducer head **124** writes a data pattern to the data fields **204** (step **300**) and then reads the data pattern from the data fields **204** to obtain ~~With reference now to **Fig. 3**, according to conventional flaw detection techniques, a pattern of magnetic polarizations is written to the disk (step 300). The channel 140 may then analyze the last n samples of the signal derived by the read element of the transducer head 124 from the disk 108. In general,~~ n-1 samples ~~are taken~~ (step **304**) and t~~. Then,~~ a next sample (the n^{th} sample) ~~is taken~~ (step **308**). The channel **140** serially determines whether each of the previous n samples ~~under consideration~~ have an amplitude that is less than a threshold value (step **312**). If at least one of the previous~~last~~ n samples has an amplitude that is greater~~more~~ than the threshold value, then the channel **140** ~~system~~ returns to step **308** to take a next sample. Otherwise,

the channel **140** reports a flaw to the controller **136** (step **316**) and returns to step **308** to take a next sample.

C~~Therefore, this c~~onventional ~~technique for detecting~~ flaw scan ~~s~~ is ~~very~~ susceptible to erroneously qualifying a series of bit cells where noise or some other disturbance ~~may~~ causes one or more samples to exceed the threshold value. As a result~~ccordingly~~, areas of the disk **108** that cannot reliably store user data may nonetheless be qualified ~~to store data due to the effects of noise~~. A~~dditionally, a~~lthough the disk drives **100** uses ~~are typically provided with~~ error correction~~ng~~ code (ECC) ~~that allows the disk drive **100**~~ to tolerate ~~at least~~ some errors, the storage ~~ability of such error correcting code to allow for the~~ reliability ~~le storage of data in areas of the disk **108** containing flaws~~ could still be compromised. Similarly, ~~this~~ conventional flaw scan~~method~~ is susceptible to erroneously disqualifying a length of the track **132** that does not contain errors in the presence of a ~~a~~ sustained noise event that causes a series of samples to fall below the threshold value. This unnecessarily reduces the storage capacity of the disk drive **100**.

Conventional flaw scan ~~In order to reduce the effects of noise, conventional flaw scanning is~~ typically makes~~performed by making~~ two or more passes over each surface of every disk **108** ~~included~~ in the ~~a~~ disk drive **100** to reduce ~~. Multiple flaw detection scans reduce the influence of~~ soft errors ~~such as may be~~ caused by random noise~~,~~ and thus increase the likelihood that flaws will be ~~accurately~~ detected and decrease the likelihood that false errors will be reported. However, multiple flaw scans ~~are undesirable, as they~~ increase manufacturing ~~the~~ time and ~~required to manufacture a hard disk drive **100** and,~~

~~therefore, increase the cost of producing a hard disk drive 100 by~~ decrease~~ing~~ manufacturing throughput.

There is, therefore, a need for a flaw scan that detects flaws and avoids false errors with high confidence. ~~Furthermore, with the limitations of conventional flaw scanning techniques, it is difficult to detect with high confidence the flaws that should be captured while rejecting false errors~~ with~~in~~ fewer ~~a single~~ passes~~. Therefore, conventional flaw scanning techniques require multiple passes if they are to detect flaws with high confidence.~~

~~For the above stated reasons, it would be desirable to provide a method and an apparatus capable of detecting flaws in a disk 108 with improved confidence. In addition, it would be advantageous to provide a method and an apparatus for detecting flaws on a disk 108 that can provide the required confidence in as few a number of scans as possible, and preferably in one pass. It would also be desirable to provide a method and an apparatus that can detect flaws on a disk with a high degree of statistical confidence, without the detection of false errors. Furthermore, it would be desirable to provide both a method and an apparatus for the detection of flaws on a disk drive 100 that are reliable in operation~~ and is ~~that are~~ inexpensive to implement.

SUMMARY OF THE INVENTION

~~In accordance with the present invention, both a method and an apparatus for detecting flaws in disks of a hard disk drive are provided.~~ The present invention detects ~~generally allows~~ flaws in storage media ~~in a disk to be detected~~ with a ~~much~~ higher degree of statistical confidence and thus ~~, thus allowing~~ fewer passes than ~~with~~

conventional flaw scan techniques using existing devices such as a PRML channel~~.~~ ~~Furthermore, the present invention produces an overall media qualification that is at least as good or better than the conventional method and does so in less time~~.

In an ~~accordance with one~~ embodiment~~ of the present invention~~, detecting flaws in a disk drive includes sampling a read signal provided by reading a data pattern from a disk to obtain samples, obtaining significant samples from the samples, deriving a value from the significant samples, and reporting a flaw if a comparison between the derived value and a threshold value is unacceptable.

In another embodiment, the data pattern is an iT pattern that includes a magnetic transition every i^{th} bit cell on a track in which it is written.

In another embodiment, the significant samples are taken at times corresponding to expected peak and near peak values in the read signal, which in turn correspond to magnetic transitions in the data pattern, and the significant samples each have an amplitude greater than 50% of an amplitude of an isolated pulse in the read signal~~and an apparatus are provided in which information written to a disk of a hard disk drive is read from the disk. The information may be written on the disk in an iT data pattern where i is an integer number. A read signal derived from the information written to the disk is periodically sampled. All or a subset of the samples derived from a discrete portion of the disk are then used to derive a value. The derived value is then compared to a threshold value. If the derived value is less than the threshold value, a flag is generated to signal the detection of a flaw~~.

~~In accordance with a further embodiment of the present invention, the information written to the disk is written in an iT pattern so as to produce a periodic signal in the~~

~~transducer head of the disk drive. This periodic signal may in turn encode a repeated pattern of data.~~

In ~~accordance with still~~ another embodiment ~~of the present invention~~, the significant samples are obtained by filtering the samples ~~data is written on the disk such that the magnetic polarity of a bit cell signals a 1 or alternatively a 0. A test pattern of data is then written on the disk. A method or apparatus in accordance with the present invention may then consider those samples of the signal taken at times corresponding to peaks or near peak samples in the readback signal. The samples under consideration may be used to derive a value for comparison with a threshold value. Based upon the comparison with the threshold value, a signal may or may not be generated to indicate the presence of a defect.~~

~~According to one embodiment of the present invention, the derived value for comparison with a threshold amount is obtained by passing a selected number of samples~~ using ~~through~~ a digital band pass filter. For example, ~~This has the result of suppressing the effects of noise on the sampled signal. Accordingly, in an embodiment in which the test~~ the data pattern is ~~written in~~ a 2T data pattern~~,~~ and the ~~the derived value is obtained by passing n samples through a digital~~ filter has a ~~that in~~ delay operator notation of $1 - D^2 + D^4 - D^6 \ldots \pm D^{2n}$~~;~~ -where n is ~~equal to~~ the number of ~~total number of~~ samples under consideration~~within the window~~. As ~~According to still~~ another example, ~~embodiment in which~~ the ~~test~~ data pattern is ~~written in~~ a 3T data pattern and ~~,~~ the ~~derived value is obtained by passing n samples through a digital~~ filter has a ~~that in~~ delay operator notation of ~~is given by the expression~~ $1 + D - D^3 - D^4 + D^6 + D^7 \ldots$

$[-/+ D^{n-1} -/+ D^n]$.

In ~~accordance with yet~~ another embodiment~~ of the present invention~~, the derived value is a sum, an average or an integration of the magnitudes of the significant samples, or of difference values between an optimal value and the magnitudes of the significant samples~~a value for comparison with a threshold value is derived by calculating a sum of the absolute value of a selected number of the samples under consideration. According to another embodiment of the present invention, the absolute value of all or a selected plurality of the n samples under consideration are integrated. According to still another embodiment of the present invention, the value for comparison with a threshold amount is derived by summing together the magnitudes of m of the n samples under consideration and dividing by m to obtain an average sampled value, where m is an integer number~~.

~~In accordance with a further embodiment of the present invention, an optimal sample level is subtracted from the absolute value of each of m samples to obtain an error value. The error values obtained for each of the m samples may then be summed, averaged or integrated. The result may then be compared to a threshold value and a defect indicated if the comparison is not favorable.~~

In ~~accordance with still~~ another embodiment, the comparison between the derived value and the threshold value is unacceptable if the derived value~~ of the apparatus of the present invention, the samples are fed into a Finite Impulse Response filter (FIR) or continuous shift register of samples that are summed into a value on every i^{th} clock cycle from all or a selected plurality of the n samples under consideration. In addition, a memory register for storing a threshold value is provided. The derived summation or value from the FIR filter is compared to the threshold value register at the input of a~~

~~comparator. The comparator generates a signal indicating a detected defect if the sum of the samples~~ is less than the threshold value~~amount~~.

Further~~Additional~~ advantages of the present invention will become readily apparent from the following discussion, particularly when taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a ~~diagrammatic representation of a~~ top view of a conventional ~~computer~~ disk drive~~,~~ with the cover removed;

Fig. 2 is a diagrammatic representation of a ~~magnetic storage~~ disk;

Fig. 3 is a ~~functional~~ flow chart ~~diagram of the operation~~ of a conventional ~~system for detecting~~ flaw scan ~~on a disk~~;

Fig. 4A illustrates a data pattern written to a track ~~depicts magnetic polarizations in a cross section of track contained~~ on the~~a~~ disk;

Fig. 4B illustrates magnetic transitions in the data pattern ~~depicts the magnetization of the cross section of track illustrated~~ in **Fig. 4A**;

Fig. 4C illustrates a read signal provided by reading the data pattern ~~an example voltage potential produced in the channel as a result of the pattern of magnetization depicted~~ in **Fig. 4A~~B~~**;

Fig. 5 illustrates ~~depicts~~ a read ~~typical~~ signal ~~produced in a channel in response to passing the transducer head through a pattern of magnetic flux, in which the signal is~~ influenced by ~~the presence of~~ intersymbol interference and a flaw;

Fig. 6 is a ~~functional~~ flow chart of a ~~diagram illustrating the operation of a system for the detection of~~ flaw scan ~~on a disk~~ in accordance with the present invention; and

Fig. 7 illustrates a functional ~~is a functional block diagram of~~ hardware diagram ~~configured~~ to implement a flaw scan in accordance with ~~an embodiment of~~ the present invention.

DETAILED DESCRIPTION

~~With reference now to~~ **Fig. 4A**~~,~~ illustrates a data pattern written to the ~~portion of a~~ track **132** along a cross-sectional portion of the track **132**. The data pattern is written to ~~to which a repeated pattern of data has been written is schematically illustrated. The section of track 132 illustrated in **Fig. 4A** can be seen to contain a number of~~ bit cells **400a-400l~~i~~**. The arrows ~~An arrow~~ in the ~~a~~ bit cells **400** indicates the magnetic polarity of the bit cells 400. In bit cells **400a, 400b, 400e, 400f, 400i** and **400j** the magnetic polarity in a first direction encodes a digital 1, and in bit cells **400c, 400d, 400g, 400h, 400k** and **400l** the magnetic polarity in a second direction encodes a digital 0. Thus, the data pattern is a 2T data pattern and the digital characters ~~If the magnetization of a bit cell in a given direction is a 1 and the magnetization of a bit cell in the opposite direction is a 0, it can be seen that the pattern of data produced by the pattern of magnetic transitions illustrated in **Fig. 4A** is such that each character is~~ alternately repeated for two bit cells 400. ~~That is, the pattern of bits is 1,1,0,0,1,1,0,0 . . . as shown in **Fig. 4A**. This is known as a 2T data pattern. In a 3T pattern, the pattern of bits is 1,1,1,0,0,0,1,1,1,0,0,0 . . . . In general, the pattern of magnetic transitions illustrated in **Fig. 4A** may be described as an iT data pattern, where i is an integer number.~~

~~With reference now to~~ Fig. **4B**~~,~~ illustrates the magnetic transitions in the data pattern~~a pattern of magnetic polarities corresponding to the pattern of magnetization shown in **Fig. 4A** is illustrated~~. The bit cells **400** as magnetized by the data pattern ~~As shown in **Fig. 4B**, a pattern of magnetic polarities written to a track 132~~ effectively forms a series of magnets **404** in the track **132**. T~~As can be appreciated, at~~ the boundaries between~~of~~ the magnets **404**~~,~~ ~~which~~ correspond to the boundaries between the bit cells **400** containing opposite magnetic polarities. Thus, the magnetic transitions occur at the boundaries between the bit cells **400b** and **400c**, **400d** and **400e**, **400f** and **400g**, **400h** and **400i**, and **400j** and **400k**. Furthermore, the ~~lines of~~ magnetic flux produced by the magnets **404** is ~~will be~~ normal to the ~~surface of the~~ disk **108** at ~~in the vicinity of~~ the boundaries and ~~disk surface. In addition, the direction of the magnetic flux will be~~ substantially parallel to ~~the surface of~~ the disk **108** ~~in areas~~ away from the boundaries.~~magnetic transitions in a longitudinal recording scheme. It should be noted that the present invention is equally applicable to a perpendicular recording scheme. As can also be appreciated, a transducer head **124** following a track **132** in close proximity to the surface of the disk **108** can sense these changes in magnetic flux. As will be understood by those of ordinary skill in the art, the changes in magnetic flux can be used to produce a voltage or a change in resistance in a read element of the transducer head **124**.~~

~~With reference now to~~ Fig. **4C**~~,~~ illustrates a read signal ~~waveform~~ **408** pro~~duced~~vided by ~~in~~ the ~~channel **140** as the~~ transducer head **124** as it passes through the magnetic flux produced by the bit cells **400** and reads the data pattern from the disk **108**~~magnetization illustrated in **Fig. 4A** is depicted~~. The read signal **408** includes peaks

412 that correspond to the magnetic transitions and zero-crossings **416** midway between the magnetic transitions. ~~In general, the waveform **408** is expressed in the channel **140** as a voltage or current signal.~~

~~By comparing **Figs. 4A** and **4C**, it can be appreciated that peaks **412** in the waveform **412** occur periodically. In particular, the peaks **412** correspond to magnetic transitions written on the track **132**. Because the amplitude at the zero crossings is expected to be zero, such samples can be discarded. Discarding samples taken at times corresponding to zero crossings improves the signal to noise ratio of an asynchronously sampled signal, as the amplitude of the retained samples, which are expected to be peak (or near peak) values, will be relatively large compared to the near zero samples, where noise can greatly affect the relative sample amplitude.~~

~~The waveform **408** illustrated in **Fig. 4C** is affected by intersymbol interference. That is, the illustrated waveform **408** is produced in connection with magnetic transitions within the track **132** that are close enough together to cause the magnetic polarizations written to the track **132** to affect the flux patterns produced by adjacent magnetic polarizations. In general, as bit cells **400** become smaller, the pattern of magnetic flux produced by magnetic transitions between the bit cells **400** become increasingly subject to intersymbol interference (*i.e.*, as the user bit density becomes greater than 1.0).~~

Fig. 5 illustrates a read signal **500** influenced by intersymbol interference and a flaw~~A waveform **500**, such as may be produced by the pattern of magnetic transitions illustrated in **Fig. 4A** in a typical disk drive **100** in which the waveform **500** is affected by intersymbol interference, is illustrated in **Fig. 5**. It can be appreciated that any disturbance of the system, such as may be produced by noise, can greatly affect how the~~

~~waveform **500** is interpreted. Therefore, it is useful to increase the signal to noise ratio in such systems. As mentioned above, it is possible to increase the signal to noise ratio by using a 2T or greater pattern and by considering only those samples taken at times that a significant non-zero value (*i.e.* a peak or near peak value) is expected.~~ The read signal **500** has a irregular waveform shape due to intersymbol interference. The read signal **500** includes peak **504** with optimal amplitude and

~~With continued reference to **Fig. 5**, it can be seen that five~~ peaks **508a**-**508e** with attenuated ~~of the example waveform **500** have an amplitude that is diminished~~ amplitude relative to the other peaks. Since t~~T~~he~~is~~ attenuated ~~diminished~~ amplitude is significantly diminished and occurs in ~~may be the result of noise and/or a flaw in the disk **108**. However, it is unlikely that noise would cause~~ five peaks in a row, it is unlikely that the attenuated amplitude is due to noise ~~to be as deeply attenuated as those illustrated in **Fig. 5**~~. Instead~~Therefore~~, the attenuated amplitude ~~attenuation~~ is probably ~~likely~~ due to a flaw in the disk **108**.

Conventional flaw scan may not detect this flaw ~~Accordingly, this attenuation is preferably detected by the channel **140** and reported to the controller **136** of the disk drive **100**. However, such a defect may not be detected using conventional flaw detection schemes~~. C~~For example,~~ onventional flaw scan may require a greater number of consecutive attenuated peaks than five~~in a row may be required~~. C~~In addition,~~ ~~c~~onventional flaw scan is also in~~techniques for detecting flaws in a disk drive **100** are less~~ sensitive to slight variations in amplitude loss, and ~~. Therefore,~~ if the read signal ~~waveform~~ 500 ~~illustrated in **Fig. 5**~~ contains a particularly deeply diminished peak~~flaw~~, ~~such as~~ illustrated as~~by~~ ~~first~~ alternate peak **512**, then ~~a~~ conventional flaw scan does

~~detection system will~~ not take this into consideration~~the relatively large attenuation of the first alternate peak 512~~. Furthermore, ~~a~~ conventional flaw scan ~~detection system~~ may fail to ~~signal the~~ detect~~ion of~~ a flaw if even one of the peaks **508**, illustrated as alternate peak **516**, ~~in a series~~ has an amplitude greater than the threshold value. ~~Therefore, even in connection with a flaw detection system that would detect a flaw after a series of five diminished peaks 508a-e, if even one of the peaks has an amplitude greater than the threshold (*e.g.*, second alternate peak 516), no flaw will be detected.~~

Fig. 6 is a flow chart of a flaw scan in accordance with the present invention. The transducer head **124** writes a data pattern to the data fields **204** (step **600**) and then reads the data pattern from the data fields **204** to obtain n–1 samples (step **604**) and then a next sample (the nth sample) (step **608**).

The channel **140** filters the n samples using a digital band pass filter to obtain m significant samples from the n samples (step **612**). The significant samples are taken (sampled) at times corresponding to the expected peak and near peak values in the read signal, which in turn correspond to the magnetic transitions in the data pattern read from the disk **108**. The significant samples each have an amplitude greater than 50% of an amplitude of an isolated pulse in the read signal. Furthermore, the significant samples each have an amplitude greater than the other samples of the n samples. Thus, the filtering passes the significant samples with the largest amplitudes and discards the other samples. For instance, the filtering passes the significant samples taken at or near the peaks **412** and discards the samples taken at or near the zero-crossings **416**.

For example, the data pattern is a 2T data pattern and the filter has a delay operator notation of $1 - D^2 + D^4 - D^6 \ldots \pm D^{2n}$. As another example, the data pattern is a

3T data pattern and the filter has a delay operator notation of $1 + D - D^3 - D^4 + D^6 + D^7 . . . [-/+ D^{n-1} -/+ D^n]$. In either case, the filtering inverts various samples so that the significant samples have the same sign, and the significant samples are determined in accordance with the data pattern and the partial response of the channel **140**.

Advantageously, the filtering increases the signal-to-noise ratio by retaining only the peak and near peak samples taken at times corresponding to the magnetic transitions in the data pattern and discarding the other samples where noise can greatly affect the signal amplitude. In particular, the filtering reduces the noise bandwidth by the square root of 1/m where m is the number of the significant samples that are considered. As a result, the channel **140** more accurately distinguishes flaws from noise~~According to the present invention, a waveform or signal (*e.g.*, **412** or **500**) produced by reading a pattern of magnetic transitions is analyzed using a peak filtering window method. In general, a selected set, or window, of samples is considered as a group in order to reduce the effects of noise on the sampled signal~~.

The channel **140** selects a predetermined number of the previous significant samples using a moving window on a first-in first-out (FIFO) basis (step **616**) and derives a value based on the selected significant samples (step **620**). As examples, the derived value is a sum, an average or an integration of the magnitudes of the significant samples, or a sum, an average or an integration of difference values between an optimal value and the magnitudes of the significant samples.

The channel **140** determines whether the derived value is less than a threshold value (step **624**). If not, then the channel **140** returns to step **608** to take a next sample.

Otherwise, the channel **140** reports a flaw to the controller **136** (step **628**) and returns to step **608** to take a next sample.

For ~~In addition, the signal to noise ratio may be increased by considering only samples taken at times corresponding to magnetic transitions (*i.e.* by considering only peak or near peak samples). According to one embodiment of the present invention, the magnitude or absolute value of the amplitude of m of the previous n samples under consideration are summed, or are integrated or averaged over m, to provide a value that can be compared to a selected threshold amount. Accordingly, the present invention effectively passes the samples under consideration through a band pass filter, reducing the noise bandwidth present in the signal by where m is the number of samples in the window that are considered. By reducing the noise in the signal, the signal to noise ratio is improved, and flaws in the disk **108** can be more accurately distinguished from noise. Accordingly, a more efficient technique for detecting flaws in a disk drive **100** is provided.~~

~~In accordance with another embodiment of the present invention, the previous n samples of a signal produced by an iT data pattern are passed through a filter that considers only those samples corresponding to expected peaks or near peaks in the signal derived from the data encoded on the disk **108**. In delay operator notation, the filter in accordance with this embodiment of the present invention for use in connection with a 2T data pattern is given by the expression~~ $\cancel{1 - D^2 + D^4 - D^6 \ldots \pm D^{2+n}}$~~, where n is equal to the total number of samples within the window. A filter in accordance with the present invention for use in connection with a 3T data pattern is given by the expression~~ $\cancel{1 + D - D^3 - D^4 + D^6 + D^7 \ldots [\ /+ D^{n-1} /+ D^n]}$~~. As can be appreciated, these filters consider~~

~~every sample corresponding to an expected peak or near peak sample in the signal derived from the written pattern, and changes the sign of the sampled values so that they are all the same. As can also be appreciated, a digital filter that passes only the most significant samples (*i.e.* samples that are expected to contain peak or near peak values) and discards the other samples can be provided for any pattern of data. A significant sample may be understood to be any signal having an amplitude that is greater than 50% of the amplitude of an isolated pulse. As will be appreciated by those of ordinary skill in the art, the partial response of the channel's detector and the data pattern chosen for flaw scan detection will affect what samples are considered significant. The sum resulting from the application of such a filter may then be compared to an acceptable or a threshold value.~~

~~As an example, if the encoded data has a 2T pattern, and m is equal to 5, the digital filter applied to the samples is given by the expression~~ $\cancel{1 - D^2 + D^4 - D^6 + D^8}$. ~~As a further example, if the samples can be quantized into integer values ranging from -30 to +30, and the optimal sample value is 16 defined by the partial response of the channel, the sum obtained by the digital filter should be m x 16 = 80 where m is equal to 5.~~

~~According to another embodiment of the present invention, the magnitude or absolute value of each of the previous significant samples are summed together. The resulting positive value is then compared to a selected acceptable or threshold value. The controller **136** is signaled that a defect has been detected if the sum of the samples are found to be unacceptable (*e.g.*, not greater than the acceptable value).~~

~~According to still another embodiment of the present invention, the sum resulting from the addition of the magnitude or absolute value of each of the previous m significant~~

~~samples is divided by m to obtain an average sampled value. The resulting average value, which will again be a positive number, may then be compared to a selected acceptable or threshold value. A defect is signaled to the controller **136** if the average value is unacceptable (*e.g.*, is less than the threshold amount).~~

~~According to still another embodiment of the present invention, the magnitude or absolute value of each of the previous m significant samples are integrated. The result of the integration is then compared to a selected acceptable or threshold value. If the integrated value is less than the selected acceptable value, a defect is indicated and the controller **136** is signaled accordingly.~~ example, the data pattern is a 2T data pattern, m is equal to 5, the filter has a delay operator notation of $1 - D^2 + D^4 - D^6 + D^8$, the samples are quantized into integer values ranging from –30 to +30, the partial response of the channel **140** defines the optimal peak amplitude as 16, the derived value is a sum of the significant samples and the sum is 5 x 16 = 80.

~~With reference now to **Fig. 6**, the operation of an embodiment of the present invention is illustrated. Initially, at step **600**, a pattern of magnetizations is written to the disk **108**. For example, in a magnetic digital system, the magnetization of a bit cell in a first direction may encode a value 1, and the magnetization of a bit cell in second direction may encode a value 0.~~

~~A repeated pattern of magnetization and therefore of encoded data, is preferably written to the disk **108** to simplify the determination of whether a bit cell produces a signal of the expected amplitude in the channel **140**. In a preferred embodiment of the present invention, the pattern of encoded information is written to all areas of a disk **108**~~

~~that can be written to after the disk drive **100** has been assembled, including the data sectors **204** and all writable areas of the servo sectors **208**. As is also noted above, the data may be written in an iT pattern, where i is an integer number, in which the direction of magnetic polarization is alternated every i bit cells. Although improvements in the signal to noise ratio may generally be realized by increasing the value of i (at least until the effective channel bit density is equal to one) it should be appreciated that the present invention is operable with any pattern of encoded data, including a 1T pattern.~~

~~Next, samples are taken from the signal derived from the transitions written to the disk. The signal or waveform is sampled once for every bit cell **400** in the length of track **132** in the window or length of track under consideration. As noted above, only the significant samples, such as the peak samples, which may include near peak samples, are preferably considered in order to increase the signal to noise ratio in the flaw detection system. Therefore, at step **604** m – 1 of the samples are considered. That is, of the previous n samples taken, the m – 1 samples corresponding to significant samples in the waveform are considered. At step **608**, a next, or mth, peak sample is taken. The magnitudes or absolute value of the amplitudes of each of the m peak samples are summed (step **612**). Alternatively, the sign of the samples may be changed so that they are all the same, and the sum of the samples may then be calculated. As still another alternative, a difference between an absolute value of each of said m values and an optional value may be calculated, and the resulting differences may be added to obtain a sum.~~

~~At step **616**, the sum derived from the previous m peak samples is compared to the selected threshold value (*i.e.*, the acceptable value). If the sum is determined to be~~

~~less than the selected threshold value, the sum is unacceptable, and the controller 136 is signaled that a defect has been detected (step 620). Alternatively, the sum may be found to be unacceptable and the controller 136 may be signaled that a defect has been detected if the sum is not greater than the threshold value. The system then returns to step 608.~~

~~If the sum of the previous m peak samples is determined to be acceptable, the system returns to step 608, at which point a next peak sample is taken. Accordingly, it can be appreciated that a moving window that includes the previous m peak samples is considered when determining whether to signal the controller 136 that a flaw requiring attention has been detected. That is, the previous m samples are considered on a first in first out (FIFO) basis. In addition, it can be appreciated that the effects of noise are diminished by considering a value derived from peak and near peak samples. That is, according to the present invention, the sample signal is subject to a band pass filter.~~

~~Although in a preferred embodiment, the m samples considered correspond to the m significant samples, it should be appreciated that, according to the present invention, m may be equal to n, the total number of samples within the window.~~

The ~~selection of a~~ threshold value ~~will~~ depends on the partial response of the ~~disk drive's 100~~ channel 140. For example, where the read signal ~~derived from the disk 108 may be~~ is quantized into integer values ranging from –30 to +30, and the ~~magnitude of the~~ optimal peak ~~signal~~ amplitude is 16, a threshold value ~~amount~~ of less than 16 is ~~would be~~ selected for comparison with an average of the absolute value of each of the previous m significant samples. Likewise, a threshold value of less than m x 16 is selected for comparison with a ~~Of course, where the~~ sum or integrated value of the absolute values of the previous m significant samples ~~are to be compared to a threshold~~

~~amount, the threshold value would be less than m x 16~~. A ~~According to one embodiment of the present invention, the~~ threshold value ~~to detect defects~~ is about 50-90% of the accumulated value is suitable~~of the expected samples~~. The threshold value also depends on the size of the defects to be detected.

~~With reference now to~~ **Fig. 7** illustrates~~,~~ a functional hardware diagram to implement a flaw scan ~~components~~ in accordance with ~~an embodiment of~~ the present invention~~ are depicted in functional block diagram form~~. A shift register **700** receives the significant samples from the filter (not shown) on a FIFO basis and ~~is provided for~~ temporarily stores the significant samples as the ~~ing t~~absolute values of their magnitudes~~he previous m significant or peak values from the window of n samples~~. The ~~The provided samples may be stored as absolute values (*i.e.*, they may represent a magnitude of the value, without reference to whether the value is positive or negative).~~ ~~The values stored in the~~ shift register **700** ~~are~~ continually feeds the significant samples ~~in~~to a summing block **704**. The summing block **704** calculates the derived value as a sum of the significant samples and the derived value (sum) ~~output from the summing block 704~~ is continually clocked to a comparator **708**. A memory **712** provides the threshold value ~~Also provided~~ to the comparator **708**~~ is a threshold value stored in memory 712~~. The ~~output of the~~ comparator **708** compares the sum with the threshold value and sends a flaw detect ~~may comprise a~~ signal ~~provided~~ to ~~the controller 136 to indicate the detection of a defect if the sum of the previous m peak samples is unacceptable. For example, according to one embodiment of the present invention,~~ the controller **136** ~~is signaled~~ if the sum ~~of the m samples~~ is less than the threshold value. In this manner, the shift

register **700**, the summing block **704** and the comparator **708** implement steps **616**, **620**, and **624** and **628**, respectively.

~~Although the hardware components that may comprise the present invention are illustrated as discrete components in **Fig. 7**, the example of **Fig. 7** is intended to be non-limiting. Furthermore, it should be appreciated that the present invention may be implemented as software code running on a microprocessor. In addition, when used in connection with a hard disk drive **100**, the present invention may be implemented as firmware code running in the controller **136** and/or channel **140** of the hard disk drive **100**.~~

A~~Furthermore, a~~lthough the present invention has been described in connection with the~~examples concerning magnetic~~ disk drive **100**~~s~~, the present invention ~~is not so limited. In particular, the present invention~~ may be applied to ~~in connection with~~ any storage ~~memory~~ device such as ~~. For instance, the present invention may be applied in connection with~~ optical, tape and~~, or~~ three~~-~~dimensional storage devices. Similarly, the present invention may be implemented in the disk drive **100** as software code running on a microprocessor or as firmware code running in the controller **136** and/or channel **140**. Likewise, although the present invention has been described in connection with a longitudinal recording disk **108**, the present invention is equally applicable to a perpendicular recording disk. And although the signal-to-noise ratio can be increased by increasing the period of an iT data pattern (at least until the effective channel bit density is one), the present invention is applicable to any data pattern including a 1T data pattern.

The foregoing discussion of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, within the skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments ~~described~~ herein~~above~~ are further intended to explain the best mode presently known of practicing the invention and to enable others skilled in the art to utilize the invention in such or in other embodiments and with various modifications required by their particular application or use of the invention. It is intended that the appended claims ~~be construed to~~ include ~~the~~ alternative embodiments to the extent permitted by the prior art.

ABSTRACT

D~~A method and apparatus for d~~etecting flaws in ~~a disk included as part of~~ a hard disk drive includes sampling a read signal provided by reading a data pattern from a disk to obtain samples, obtaining significant samples from the samples, deriving a value from the significant samples, and reporting a flaw if a comparison between the derived value and a threshold value is unacceptable.~~are provided. A signal derived from data encoded on the disk is sampled. All or a subset of the n samples derived from a discrete portion of the disk are then used to derive a value. For example, the previous m significant samples are used to derive a value. The value may be derived by calculating a sum of the previous m samples, by integrating the previous m samples, by calculating an average of the previous m samples or by passing the previous m samples through a filter. The derived value is then compared to a threshold value. If the derived value is less than the threshold value, the controller of the disk drive is signaled to indicated that a flaw has been detected. The present invention allows flaws on disks or other storage media to be detected with improved accuracy.~~